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Aging Of Farm-Cured Hams As Affected By Method Of *Cutting, Curing, and Smoking*

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Aging of Farm-Cured Hams As Affected by Method of *Cutting, Curing, and Smoking*[1]

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Since 1950 a geat deal of research has been conducted on the curing and aging of hams by farm methods. This work was initiated because of serious spoilage in country-style hams. It has been estimated that 50 million pounds of cured meat is lost annually in the Southern States alone (*20*).[2] Just how much of this loss is due to curing failures and how much is due to unsuccessful aging is not known (*12*). Certainly, inadequate curing could lead to unsuccessful aging; and that poor aging probably contributes to spoilage is shown by increased use of freezer storage or refrigeration for cured hams (*4*, *20*). Although the use of refrigeration may indicate a preference either for mildly cured ham or for the flavor of freshly cured ham (*25*), it is also believed to show the uncertainty of successful aging. One has only to read the proceedings of the Reciprocal Meat Conferences[3] to learn that storage of hams under farm conditions is a perennial problem for extension meat specialists.

This publication summarizes the results of published and unpublished early work on the project and reports the results of additional experiments on smoking, curing, and method of cutting hams, including chemical and organoleptic analyses and bacteriological studies.

REVIEW OF EARLY WORK

In early work on this project, Dunker and Hankins (*6*) surveyed the meat-curing methods employed by farmers. Spoilage was reported by only 3.2 percent of the farmers reporting. However,

[1] This publication reports aspects of a long-time research project on ham curing begun under the Research and Marketing Act of 1946. The work was done at the Meat Laboratory of the Eastern Utilization Research and Development Division, Beltsville, Md. Many persons contributed to parts of the study and the authors particularly wish to acknowledge the assistance of Nina B. Hess, Melvin D. Fields, John A. Alford, George T. Currie, Felix C. Ross, and Nevin C. Bollinger.

[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

[3] Proceedings of the annual conferences are published in mimeographed form by the National Live Stock and Meat Board, 36 South Wabash Ave., Chicago, Ill.

Dunker and Hankins felt that not only the curing time but also the number of overhauls (number of times the drying mixture was applied in dry curing and number of times the meat was repacked in the brine in brine curing) and the frequent omission of smoking fell short of safe practices for storage under farm conditions. On the basis of these findings, an investigation of factors influencing the aging of farm-cured hams was considered timely.

The survey of Dunker and Hankins (*6*) showed that four basic methods are used in farm curing: dry cure, brine cure, brine pumping plus brine cure, and brine pumping plus dry cure. Curing agents used are salt only; home mixtures of salt, sugar, pepper, and nitrate; and commercial mixtures.

The farm-curing methods summarized by Dunker and Hankins (*6*) were duplicated at the Meat Laboratory, and the resulting cured hams were stored at 38°, 70°, or 90° F. either immediately after curing or immediately after curing and smoking.

The results of part of this research—hams dry-cured with salt only (10 pounds of salt per 100 pounds of meat for 1½ days per pound)—have been reported by Fields, Dunker, and Swift (*9*). General conclusions from this study were that hams stored 6 months at 70° were over-aged and those stored 6 months at 90° were undesirable. The investigators felt that these constant temperatures were more drastic than actual farm practices. This conclusion did not take into account that these hams were cured one-half day per pound (25 percent) less than is generally recommended (*25*) and that they were stored without a conditioning period for equalization of the absorbed salt. Specifically, the data indicated that the hams varied greatly in stability and total salt content (3.48 to 5.30 percent) at time of storage.

The results of the remainder of the work were not published, but may be summarized as follows:

Among 317 hams processed by the three other methods of farm curing and stored *immediately*, 89 were tested organoleptically; 51.6 percent of those tested had developed poor flavor or outright spoilage. Hams were stored at temperatures of 38°, 70°, and 90° F. for 6 weeks, 6 months, and 12 months. For each storage period, there was poor flavor or deterioration at 38° in 20, 12.5, and 20 percent of the hams; at 70°, in 10, 56, and 50 percent; and at 90° in 60, 80, and 100 percent. Differences were not great enough to warrant a breakdown by method of curing. These hams underwent a severe test of stability. Aside from possibly inadequate time in cure reported in the survey by Dunker and Hankins (*6*), the hams were placed in aging storage immediately after curing. This did not allow time for salt equalization, which takes place at a variable and slow rate (*1*, *18*, *19*). These results, then, are an exaggerated example of the spoilage potential of hams aged under farm conditions.

Earlier workers at the Meat Laboratory assumed that similar treatment of individual hams would give similar results. Therefore, organoleptic and chemical and bacteriological determinations were made on separate hams (*6–9*, *23*). To more effectually examine isolated factors influencing the aging of hams, the method of sampling in the study reported here was changed so that organoleptic, chemical, and

bacteriological determinations were made from samples taken from the same ham.

MATERIALS AND METHODS

Data are reported for 318 hams cured and otherwise processed. The hams weighed an average of about 16 pounds and, except as noted, were short cut (square cut). They were from hogs of known history.

The organoleptic sample was obtained by removing a 3-inch cut adjacent and parallel to the aitch bone. This cut was wrapped in aluminum foil and baked to an internal temperature of 168° F. at an oven temperature of 257°. After the ham had been chilled in the refrigerator, slices were tested as described by Weir and Dunker (*23*). The following scale, in which the larger scores indicate greater salt intensity and desirability, was used:

Score	*Salt intensity*	*Flavor desirability*
5	Pronounced	Very desirable.
4	Moderately pronounced	Desirable.
3	Slightly pronounced	Slightly desirable.
2	Perceptible	Acceptable.
1	Imperceptible	Undesirable.

Chemical studies were made on composite samples of lean and fat by the methods used by Fields and Dunker (*8*). Determinations of salt distribution were made on dissected *semimembranosus*, *vastus intermedius*, and *biceps femoris* and other muscles (fig. 1) taken from slices removed adjacent to the organoleptic sample (*1*).

Bacteriological samples were taken, examined, and evaluated as described by Dunker, Berman, Snider, and Tubiash (*7*).

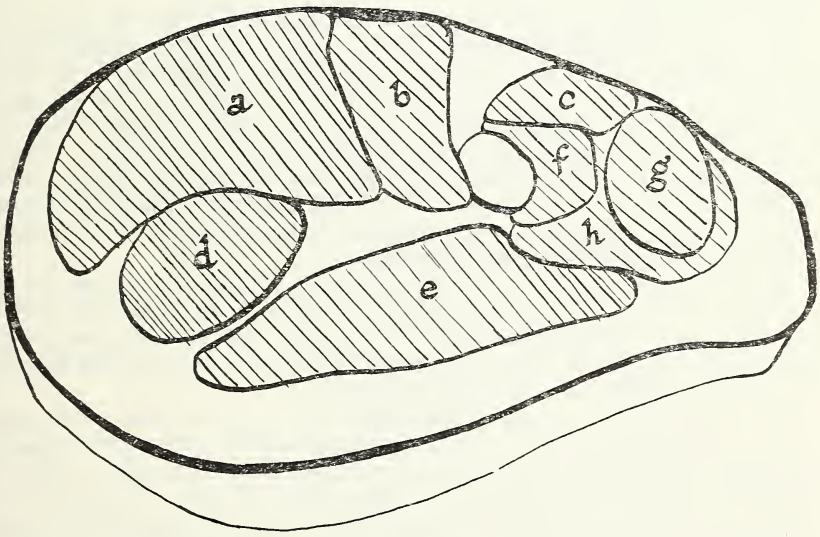

FIGURE 1.—Muscle segments in cross-section slice of a ham: (*a*), *Semimembranosus;* (*b*), *adductor;* (*c*), *vastus medialis;* (*d*), *semitendenosus;* (*e*), *biceps femoris;* (*f*), *vastus intermedius;* (*g*), *rectus femoris;* and (*h*), *vastus lateralis.*

EXPERIMENTAL RESULTS AND DISCUSSION

Characteristics of Typical Farm-Cured Aged Hams

To obtain representative data, typical farm-cured aged hams from 6 months to 2 years old were obtained from Georgia, Missouri, North Carolina, Pennsylvania, and Virginia. These hams were compared with Smithfield hams studied by earlier workers (*7–9*, *23*) on this project (table 1). Ranges for most of the properties of farm-cured aged hams were much wider than those for the Smithfield hams. This is attributed to differences in curing methods, handling, and storage conditions. However, ranges in organoleptic characteristics were similar.

These data served as model and reference for the studies reported here.

Conditioning

Immediately after curing, and also after smoking, a ham is not in a uniform state. Some investigators (*12*, *13*, *18*) have recognized the importance of a tempering or conditioning period when hams are to be aged.

Traditionally, farmers slaughtered their hogs in the fall as soon as temperatures permitted. After the hams were cured, they were held throughout the winter and early spring. This interval of 5 to 6 months was a natural conditioning period. The value of this conditioning period appears to have been overlooked, although it may have much to do with the keeping quality and flavor of the famed country-styled aged hams.

Table 2 shows the effect of a conditioning period on the aging of hams. Hams brine pumped plus brine cured with a commercial mixture containing smoke ingredients by a typical farm method (2 days per pound) and stored immediately at 70° F. deteriorated very rapidly (*6*). Hams similarly cured but smoked a short period before storage were in moderately good condition after 6 months. Hams brine cured by a standard commercial method (4 days per pound) and smoked before storage were in fair condition after 6 months. These results indicate that salt distribution was improved by brine pumping, which is the objective of that procedure.

Brine-pumped plus brine-cured hams are particularly vulnerable to spoilage. The large amount of water introduced raises the salt-moisture ratio and has been reported to retard salt distribution (*19*). Drying was apparently the main function of the short smoking period that was so effective in these experiments.

Hams dry cured and aged immediately after curing were below par after 4 months of storage, but they deteriorated at a slower rate than unsmoked hams that had been brine pumped plus brine cured. However, dry-cured hams conditioned either at 38° F. or by storage in an outside smokehouse during the winter were in good shape after being held from 3 to 4 months at 70°, and those conditioned for longer periods were even better. Miller and Zeigler (*18*, *19*) advised a 30-day conditioning period at 40°; Hunt and others (*13*) reported beneficial

TABLE 1.—*Properties of Smithfield-type and typical farm-cured aged hams*

Source of ham	Age	Moisture	Nitrogen		Free fatty acids	Salt	Salt intensity	Desirability of flavor of—		Salt-moisture ratio
			Nonprotein	Soluble				Lean	Fat	
	Months	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Score*	*Score*	*Score*	
Smithfield-type (range)	12–17	49. 8–53. 2	26. 0–27. 6	33. 9–36. 6	8. 4–10. 9	7. 8–10. 9	2. 4–2. 9	2. 4–3. 9	2. 5–3. 8	1: 5. 3 1: 6. 8
Georgia	6	52. 9	20. 5	30. 9	3. 2	10. 1	2. 1	2. 1	2. 4	1: 5. 2
Missouri	6	48. 0	30. 6	41. 7	----------	7. 1	2. 5	3. 8	3. 7	1: 6. 8
	12	49. 0	37. 1	45. 5	----------	6. 6	2. 3	3. 7	2. 3	1: 7. 4
	24	35. 1	32. 4	38. 5	----------	7. 9	2. 5	2. 8	4. 0	1: 4. 4
	24	31. 2	33. 7	35. 5	----------	7. 9	2. 7	2. 8	2. 7	1: 3. 9
North Carolina	6	54. 8	26. 6	39. 0	9. 3	8. 4	2. 1	3. 9	3. 0	1: 6. 5
Pennsylvania	6	55. 9	30. 6	43. 8	6. 7	5. 4	1. 6	3. 0	2. 8	1: 10. 4
	6	57. 9	33. 5	46. 3	9. 3	5. 0	2. 0	3. 5	2. 7	1: 11. 6
Virginia	7	50. 5	25. 4	37. 1	6. 0	9. 6	3. 0	2. 2	3. 0	1: 5. 3
	7	53. 8	32. 8	46. 8	17. 5	4. 6	2. 0	3. 7	3. 5	1: 11. 7
	7	51. 2	31. 8	46. 9	17. 1	3. 5	2. 0	3. 7	3. 3	1: 14. 3

TABLE 2.—*Comparison of hams cured by typical farm methods and stored under various conditions*

Method of curing, storage temperature, and time [1]	Gain (+) or loss (−) during—				Free fatty acids	Salt	Salt-moisture ratio	Salt intensity	Desirability of flavor of lean
	Curing	Smoking	Conditioning	Storage					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Score*	*Score*
Brine-pumped plus brine-cured:									
Control (no storage) [2]	+9.9				0.8	3.9	1:17.8		
Stored at 70° F. for—									
8 weeks	+5.9			−10.6	5.6	5.8	1:10.8	1.8	1.0
	+11.4			−5.4	4.4	7.0	1: 9.0	1.8	1.3
	+9.5			−5.9	4.7	6.7	1: 9.3	1.8	1.0
6 months	+9.8			−25.8	9.2	8.4	1: 6.7		[3] 0
	+9.5			−15.4	8.3	9.1	1: 6.4		0
	+11.8			−14.9	13.7	8.4	1: 6.9		0
	+7.6	[4] 0		−22.1	1.4	7.5	1: 7.5	2.8	2.5
	+9.7	−1.3		−24.5	1.8	9.4	1: 5.4	2.8	2.5
	+7.9	0		−23.2	1.3	8.1	1: 6.7	2.8	3.5
Brine-cured:									
Control (no storage) [2]	+8.6	[5] 0			1.3	4.5	1:14.9	2.1	3.7
Stored at 40° F. for 8 weeks [2]	+6.4	−1.1		−1.6	2.2	4.5	1:14.2	2.3	3.9
Stored at 70° F. for 6 months	+5.7	−1.7		−19.4	10.7	6.2	1: 8.8	2.2	1.6
	+7.3	−3.9		−25.9	7.5	7.8	1: 7.1	2.4	2.0
	+8.1	−.7		−22.9	10.2	8.7	1: 6.2	2.6	2.8
Dry-cured and stored at 70° F. for—									
1½ months	−3.2			−12.1	6.7	5.9		2.3	3.5
2 months	−3.5			−12.7	3.1	6.0		1.8	3.0
2½ months	−5.5			−11.2	3.8	6.6		1.8	3.8
3 months	−3.6			−14.6	5.6	6.9		1.8	3.0
3½ months	−3.6			−20.6	7.0	7.3		2.2	2.8
4 months	−4.6			−18.8	12.5	7.5		2.0	2.0
	−4.1			−13.3	10.2	4.0			0
4½ months	−3.8			−19.1		7.0		2.0	2.2
	−3.8			−18.5		6.6		2.2	2.3
5 months	−2.3			−16.1		4.8		1.2	1.5

6 months	−2.6	--------	----------	−17.1	11.0	6.6	--------	--------	0
7 months	−4.0	--------	----------	−36.4	--------	7.4	--------	2.0	2.1
	−4.5	--------	----------	−22.7	9.3	7.1	--------	1.8	2.6
3 months	−4.1	--------	[6]−6.4	−21.6	8.6	8.2	1: 7.3	2.3	2.8
	−3.2	--------	[7]−10.4	−22.1	8.9	8.6	1: 6.6	2.2	2.5
4 months	−4.7	--------	[8]−9.3	−23.3	12.4	8.1	1: 7.2	2.2	3.2
	−4.5	--------	[9]−13.5	−25.8	10.4	7.5	1: 7.9	2.2	3.3
	−3.8	--------	[10]−15.4	−18.6	9.5	9.5	1: 5.9	2.3	3.1

[1] Hams were cured as follows: Brine-pumped plus brine-cured hams were pumped (8-percent gain) with 85°-s.g. brine and cured 2 days per pound in 71°-s.g. brine. Brine-cured hams were cured 4 days per pound in an 8–2–2 brine. Dry-cured hams were cured 2 days per pound in an 8–2–2 formula and smoked 8 hours at 135°–170° F. (*22*).

[2] Average of 3 hams.

[3] Inedible.

[4] 8 hours at 135°–170° F.

[5] 8 hours at 120° F.

[6] 4 weeks at 38° F.

[7] 4 weeks in outside smokehouse in winter.

[8] 8 weeks at 38° F.

[9] 8 weeks in outside smokehouse in winter.

[10] 12 weeks in outside smokehouse in winter.

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results for dry-cured hams from a 2-week "air cure." As indicated earlier, equalization of salt in the muscles is a slow process. Shrinkage (drying), which occurs during conditioning, is also a slow process. It reduces the salt-moisture ratio and improves stability. The data generally indicate that water content should be reduced about 10 or 15 percent before aging.

Aged hams are successfully produced commercially under carefully controlled conditions of curing, processing, and storage. Such conditions are not available to farmers who must rely on the cold weather of winter to prepare the hams for summer's climatic hazards. The chief danger is that the importance of this fact will be overlooked. Hams cured in late winter or early spring may not mature sufficiently to withstand summer temperatures. The advent of locker plants may have aggravated the situation since cured hams can be produced throughout the year and might be subjected to farm aging conditions before adequate preparation.

Smoking

Data in table 2 show that smoking had a beneficial effect on brine-pumped plus brine-cured hams. Similarly cured unsmoked hams quickly spoiled. Some drying and possibly some conditioning occurred during smoking. Smoke ingredients apparently were not a factor since the curing mixture contained smoke additives.

As shown in table 3, aged hams smoked either before or after the conditioning period tended to grade higher than similarly prepared unsmoked hams (table 2).

Many farmers do not smoke their hams (*6*). However, smoking is generally considered to improve quality and stability (*22*), and it has been noted to have bactericidal and antioxidant effects (*10*) even though it is considered to be superficial in action (*21*). Haynes and Schmitt (*12*) showed that smoking has a slight drying action and thereby tends to raise the interior salt level of the ham. On the other hand, the condition of the surface of hams has been found to have no effect on their internal stability (*24*). It is, therefore, difficult to explain the effectiveness of smoking shown here.

A long smoking period at a temperature of 90° F. is frequently recommended for the best aged flavor in hams (*5*, *17*, *22*). However, according to many reports, higher temperatures are frequently used. Actually, it may be difficult for farmers to control smoking temperature. The hams compared here were smoked at 100°, 120°, 140°, and 170° F. As the data indicate, all aged well and were scored at about the same level of desirability. At the higher temperatures, differences in flavor were observed, and color was not as good. Difference in flavor might prove to be a useful measure of quality and deserves closer and more detailed scrutiny. Kemp, Moody, and Varney (*17*) reported on the effect of smoking hams to internal temperatures of 95°, 110°, 125°, and 140°. They observed poor color and tissue structure at 125° and 140° but little difference in flavor.

TABLE 3.—*Effects of time and temperature of smoking on shrinkage of dry-cured hams* [1]

Smoking temperature and time	Shrinkage during—					Salt	Salt intensity	Desirability of flavor of lean
	Curing	Conditioning before smoking	Smoking	Conditioning 12 weeks at 38° F. after smoking	Storage			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Score*	*Score*
100° F.:								
26 hours	−5.9	----------	−8.8	−15.3	−24.7	7.9	2.3	3.7
47 hours	−7.3	----------	−11.8	−16.4	−25.4	9.1	2.4	4.6
120° F.:								
47 hours	−4.3	----------	−9.3	−13.7	−26.1	6.9	2.3	3.5
64 hours	−4.9	----------	−11.1	−16.0	−27.2	8.0	2.2	3.3
140° F.:								
26 hours	−4.7	----------	−10.5	[2]−17.4	−24.4	8.1	1.8	3.8
	−6.4	----------	−10.9	−17.9	−27.7	9.1	2.2	4.2
35 hours	−4.8	----------	−9.5	−15.4	−23.8	9.3	2.4	3.6
120° F.: 26 hours	−4.9	[3]−14.8	−16.0	----------	−22.2	8.6	2.5	3.2
	−5.0	[2]−17.4	−18.0	----------	−26.7	7.0	2.2	3.7
	−3.4	[4]−12.2	−14.9	----------	−22.3	7.1	2.0	3.2
170° F.:								
7 hours	−3.8	[5]−15.0	−15.6	----------	−23.1	6.2	2.0	3.5
14 hours	−3.7	[5]−13.7	−14.3	----------	−21.7	5.7	2.0	3.5
	−3.2	[5]−10.9	−12.9	----------	−20.6	5.4	1.8	3.5

[1] All hams were dry cured with 10–2–2 formula per 100 pounds for 2 days per pound and stored 4 months at 70° F.
[2] 12 weeks in outside smokehouse in winter.
[3] 8 weeks in outside smokehouse in winter.
[4] 16 weeks at 38° F.
[5] 14 weeks in outside smokehouse in winter.

Curing

Proper conditioning and smoking of hams may not suffice if enough salt is not absorbed into the meat during curing. Fields, Dunker, and Swift (*9*) reported that hams dry cured with 10 pounds of salt per 100 pounds of meat for 1½ days per pound ranged in salt content from 3.48 to 5.30 percent. Haynes and Schmitt (*12*) using 6 pounds of salt per 100 pounds of meat for 2½ days per pound, observed much variation and a mean potential total salt content of about 3.8 percent after curing and smoking. Thus, it probably ranged from about 2.9 to 4.7 percent. Ingram (*14*, *15*) found that 5 percent was a safe salt content.

Most instructions for curing country hams recommend dry curing with 6 to 8 pounds of salt per 100 pounds of meat. This is done to prevent excessive saltiness (*5*, *18*, *25*). However, a considerable percentage of hams so cured will have potential equalized salt contents well below 5 percent and they may age poorly or spoil under rigorous or farm conditions of storage. A ham that contains 5 percent of salt and 65 percent of moisture after curing and smoking will, on shrinkage (drying) to a moisture content of 50 percent, contain 8.4 percent of salt, which is within the range of Smithfield hams shown in table 1.

A study was made of hams dry cured with 6, 8, 10, and 12 pounds of salt per 100 pounds of meat. The salt was carefully applied, and the number of applications was adjusted to the amount of salt used. Ample curing time was allowed, and the hams were smoked and conditioned before aging 4 months. Results are represented by the data in table 4.

With increased amounts of salt, desirability of flavor increased, percentage of failures decreased, and range of desirability narrowed. These data indicate that stronger dry curing than generally used by farmers will protect hams against spoilage when they are aged under rigorous conditions. However, there is a strong trend toward milder curing (*25*).

Christian (*5*) states that for all-around acceptance, aged country ham should have a salt and a moisture content of 5 to 6 percent and 55 to 57 percent, respectively. Based on a moisture content of 65.1 percent after curing and smoking, this would require an original salt content of 3.88 to 4.87 percent, which borders on the impractical. Such a ham could be consistently produced only under carefully controlled conditions.

In general, for farm conditions, from 9 to 12 pounds of salt per 100 pounds of meat apparently is required in dry curing. This amount is necessary either because of the low capacity of some hams to absorb the salt or because of some inherent chemical (*3*) or bacteriological state of the ham. But the amount of salt used may be safely reduced if enough shrinkage (drying) before aging is obtained to bring the salt-moisture ratio to a sufficiently low level. Hankins and associates (*11*) found that bacon containing 3 percent of salt could be stabilized for storage at 37° C. (98.6° F.) by reducing the salt-moisture ratio to 1:5. The proper ratio for hams would appear to be about 1:13

before aging storage. Hams dehydrate very slowly, and it is impractical and inadvisable to dehydrate them under forced conditions such as heating (*12*) (table 5).

In dry curing, the method preferred by most farmers, salt that should be absorbed falls off or is drained off by exuding fluid. The method is simple and rapid, and the shrinkage that occurs during curing is advantageous as a preparation for aging storage. However, shrinkage during dry curing would not seem so important when a winter-long period is available for conditioning. It has been reported that salt equalization is more rapid in dry curing than in brine curing (*19*). As shown in table 6, after 63 days in brine at five concentrations, the salt content was still dangerously low in the *biceps femoris* muscle at all concentrations.

In another study (table 7), hams cured by three brine-curing formulas were compared with dry-cured hams. All were processed and aged under conditions approximating those on the farm.

Hams were brine cured for 4 days per pound by one of the formulas: 8–8–2, 9–8–2, or 10–8–2 (pounds salt, pounds sugar, and ounces nitrate). The brines contained 10.12, 12.5, and 14.0 percent of salt, respectively. The 10–8–2 formula brine had a salt content equivalent to the 8–2–2 formula 71° brine. These hams were compared with hams dry cured with 8 pounds of salt per 100 pounds of meat (8–8–2 formula) for 2 days per pound. The amount of sugar used in these cures was unorthodox, but Brady and associates (*2*) have reported that sugar has no significant effect on the quality of aged hams.

Table 7 shows that salt distribution was better in hams dry cured and conditioned 43 days before smoking than in hams brine cured and conditioned 18 days before smoking. Results of a 4-month conditioning period followed by aging 4 months outside in the summer, with or without smoking, or by aging 4 months at 70° F. are summarized as follows:

Hams cured in 14-percent brine (10–8–2 formula) were best overall. They had the best average and narrowest range in desirability of flavor and the lowest salt-moisture ratio. Hams dry cured and those cured in 12.5-percent brine (9–8–2 formula) ranked second and were similar to each other. Dry-cured hams were better than those cured in the strongest brine (10–8–2 formula) only when the 4-month conditioning period was omitted. The 10–8–2 formula brine was the same in salt content as the 8–8–2 formula 71° brine, which is commonly used and is considered comparable to dry curing in 8 pounds of salt per 100 pounds of meat. These results indicate that salt absorption may be more uniform in brine curing than in dry curing. However, sufficient time for salt equalization and shrinkage must be permitted.

A frequently used method of speeding salt equalization is to pump brine into hams by stitch pumping before applying regular curing procedures. An experiment (table 5) was conducted to compare (1) brine-pumped plus brine-cured hams and (2) brine-pumped plus dry-cured hams with dry-cured hams.

Two lots of hams were stitch-pumped with saturated brine (8–2–2 formula) to a gain of 6.25 percent in weight by a modification of the

TABLE 4.—*Effect of increasing salt content in dry-curing formula on keeping quality of ham*

Dry-cure formula [1]	Time in cure	Conditioning at 38° F.		Shrinkage during aging for 4 months		Salt	Salt in muscles			Desirability of flavor of lean
		Days	Shrinkage				Outside, *semimembranosus*	Center, *vastus intermedius*	Bottom, *biceps femoris*	
	Days	*Number*	*Percent*	*° F.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Score*
6–2–2	30	45	11.0	70	22.4	5.7	3.7	4.0	3.6	0
	30	45	14.2	60	23.7	4.3	3.1	4.2	3.4	3.1
	30	45	14.3	60	24.3	3.5	3.5	4.4	3.5	0
	34	35	10.1	(2)	21.2	6.5	6.5	7.3	6.7	3.0
	34	35	11.7	70	25.4	6.8	6.5	7.7	7.7	4.2
	34	35	12.6	70	26.0	7.6	8.1	9.5	8.4	2.8
Average								6.2		2.2
Range										4.2
8–2–2	30	30	15.4	70	26.8	3.5	3.4	4.3	3.1	0
	30	30	15.9	70	27.8	5.0	3.6	4.1	3.4	2.5
	30	30	13.3	60	29.3	7.4	5.5	6.5	5.7	3.0
	30	30	10.7	60	23.0	7.0	5.3	5.5	5.2	3.8
	41	28	13.9	(2)	28.9	9.2	9.8	11.0	10.1	2.7
	41	28	10.0	70	23.5	10.4	10.8	11.8	10.9	3.8
Average								7.1		2.8
Range										3.8
10–2–2	30	30	8.9	70	16.9	6.3	4.9	5.1	4.1	2.4
	45	40	14.2	60	25.9	6.9	5.6	6.8	5.7	3.5
	48	21	13.2	(2)	21.2	12.7	9.8	10.4	10.2	3.5
	48	21	14.8	(2)	21.9	10.7	11.7	7.7	10.4	4.2
	48	21	13.6	(2)	27.1	11.2	10.4	11.4	10.9	3.8
	48	21	7.1	70	18.1	6.9	7.3	7.7	6.8	4.2

Average								8.2		3.6
Range										1.8
12–2–2	30	30	14.5	70	24.0	7.5	6.1	7.0	5.6	3.3
	37	18	10.6	60	21.9	11.5	11.5	10.9	9.6	3.9
	37	18	11.5	70	22.3	11.5	11.5	10.9	9.6	3.9
	37	18	12.0	70	23.0	10.1	7.4	9.1	7.5	4.3
	55	14	8.9	70	21.9	10.5	9.7	11.0	10.1	4.5
	55	14	9.6	(2)	23.3	8.5	8.3	8.9	8.3	4.2
Average								9.6		4.0
Range										1.2

[1] Pounds salt, pounds sugar, and ounces nitrate applied per hundred pounds of meat.

[2] In outside smokehouse in summer.

TABLE 5.—*Brine-pumped plus brine-cured hams and brine-pumped plus dry-cured hams compared with dry-cured hams*

Kind of cure	Loss (−) or gain (+) during—					Salt-moisture ratio in muscles			Desirability of flavor of lean [1]
	Curing	Conditioning at 38° F. before smoking		Smoking 4 days at 120° F.	Storage 4 months at 70° F.	Outside, *semimembranosus*	Center, *vastus intermedius*	Bottom, *biceps femoris*	
	Percent	*Days*	*Percent*	*Percent*	*Percent*				*Score*
Brine pumped plus—									
Brine cured	+9.19	8	+6.5	-------	-------	1: 8.7	-------	1:19	2.8
Dry cured	+.70	15	−2.6	-------	-------	1:13.9	-------	1:27.9	2.2
Dry cured	−5.03	15	−7.1	-------	-------	1: 9.7	-------	1:27	2.8
Brine pumped plus—									
Brine cured	+9.63	22	+2.2	−1.95	-------	-------	1:10.7	-------	3.8
Dry cured	+1.81	30	−4.3	−6.13	-------	-------	1:15	-------	3.5
Dry cured	−1.01	30	−6.3	−8.75	-------	-------	1:11.4	-------	4.0
Brine pumped plus—									
Brine cured	+10.68	27	+3.75	−1.03	−10.01	1: 6.8	1: 6.8	1: 8.5	3.8
Dry cured	+1.23	33	−.78	−10.2	−19.48	1: 8.1	1: 8.3	1: 8.4	3.2
Dry cured	−2.22	30	−6.72	−9.5	−16.49	1: 8.6	1: 8.6	1:10.4	3.2
Brine pumped plus—									
Brine cured	+8.95	25	+1.97	-------	−17.84	1: 4.9	1: 6.0	1: 6.6	2.7
Dry cured	+3.17	33	−3.73	-------	−15.81	1:11.9	1:14	1:16.5	1.2
Dry cured	−2.82	33	−8.01	-------	−22.90	1:16.2	1:10.3	1:13.0	2.7
Brine pumped plus—									
Brine cured	+14.95	19	+8.74	+1.95	−13.71	1: 5.6	1: 5.3	1: 6.3	3.3
Dry cured	+.94	27	−4.52	−6.52	−16.08	1:13.1	1:13.9	1:14.2	0
Dry cured	−2.34	27	−6.90	−9.37	−19.12	1:10.1	1: 8.8	1: 8.6	3.7
Brine pumped plus—									
Brine cured	+11.15	[2] 4	−1.11	−2.77	−13.88	1: 6.1	1: 7.6	1: 7.4	2.7
Dry cured	+1.85	[2] 12	−7.72	−8.77	−20.49	1:11.9	1:11.7	1:11.9	1.3
Dry cured	−2.73	[2] 12	−11.49	−13.13	−22.74	1: 6.9	1: 6.4	1: 6.8	1.3

[1] Brine pumped plus brine cured: Average, 3.1; range, 2.7–3.8. Brine pumped plus dry cured: Average, 1.4; range, 0–3.2. Dry cured: Average, 2.7; range, 1.3–3.7.

[2] Heated 4 days at 100° F. and 7 days at 103° F.

TABLE 6.—*Effect of concentration of salt in brine on absorption and distribution of salt in muscles of ham*

Salt in brine (percent) [1]	Outside muscles		Center muscles		Bottom muscles	
	Moisture	Salt	Moisture	Salt	Moisture	Salt
	Semimembranosus		*Vastus intermedius*		*Biceps femoris*	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	71. 75	-------	74. 60	-------	74. 49	-------
5. 28	67. 78	3. 38	71. 70	1. 25	70. 97	1. 07
10. 56	74. 40	4. 10	70. 13	2. 47	72. 25	1. 92
18. 84	58. 99	9. 19	62. 28	5. 72	70. 49	2. 70
21. 12	56. 28	10. 34	63. 93	5. 80	68. 50	2. 91
26. 40	57. 69	11. 57	67. 01	5. 02	69. 87	3. 81
	Adductor		*Rectus femoris*		*Vastus lateralis*	
0	75. 57	-------	75. 67	-------	75. 76	-------
5. 28	69. 98	2. 75	72. 75	2. 20	72. 07	1. 58
10. 56	68. 04	5. 87	68. 97	5. 51	72. 36	2. 82
18. 84	65. 79	5. 71	63. 83	8. 43	67. 87	5. 59
21. 12	62. 11	8. 02	63. 06	8. 73	66. 08	5. 30
26. 40	59. 17	9. 65	59. 20	10. 68	65. 12	6. 79
	Vastus medialis		*Semitendinosus*			
0	75. 24	-------	72. 57	-------		
5. 28	70. 34	2. 34	65. 43	1. 71		
10. 56	67. 19	5. 29	67. 97	2. 63		
18. 84	70. 28	2. 87	66. 85	3. 64		
21. 12	59. 87	8. 23	61. 59	5. 48		
26. 40	56. 39	10. 56	64. 08	5. 69		

[1] All hams soaked in brine for 63 days; 0, 5.28, and 10.56 percent represent left hams from 3 animals; 18.84, 21.12, and 26.40 percent represent right hams from same 3 animals.

method of Bitter.[4] Four sites (sites 1, 2, 5, and 9) were used instead of the 11 sites used by Bitter. One lot was then brine cured in 71° brine (8–2–2 formula) for 2½ days per pound; the other lot was dry cured with 5 pounds of salt (8–2–2 formula) per 100 pounds of meat for 2 days per pound. These two lots were compared with hams dry cured with 8 pounds of salt (8–2–2 formula) per 100 pounds of meat. This experiment was designed to make available the same amount of salt for absorption and was based on the following assumptions: (1) Dry curing by the method used results in hams with a salt content of about 4 percent; (2) the amount of saturated brine used for pumping would introduce 1.5 percent of salt; and (3) dry curing is about twice as fast as brine curing. Results are shown in table 5.

Brine-pumped plus brine-cured hams conditioned for 8 days were compared with dry-cured hams conditioned for 15 days. Salt distri-

[4] BITTER, H. L. PRACTICAL ASPECTS OF HAM CURING AS THEY AFFECT QUALITY. 30 pp. (Thesis, Univ. Md., College Park.)

bution was better in the former, although it was not completely equalized.

In another test, hams were cured by the three methods, with and without smoking, followed by moderate conditioning periods before they were stored at 70° F. The brine-pumped plus brine-cured hams were consistently best. Dry-cured hams were second. Brine-pumped plus dry-cured hams were very poor. Salt absorption by these hams appeared to be particularly slow and variable. Possibly because of excess moisture in the hams, some of the dry-cured mixture was lost before it could be absorbed. Salt absorption by brine-pumped plus brine-cured hams was somewhat higher and much more uniform.

Method of Cutting

Hams are cut two ways (*23*) : at a point just behind the pelvic arch (long-cut ham) and 2 inches from the aitch bone (short- or square-cut ham). Commercially aged hams are long cut and formerly all farm-cured hams were also long cut. There is a strong trend among farmers toward the short-cut ham, and the hams in these experiments were this type.

No one seems to have considered the possibility that short-cut hams might be more likely to spoil than long-cut hams. The reason given by commercial operators for using the long cut is that the short cut shrinks more. In considering structures, the long-cut ham appears to be a more natural cut and possibly better protected internally.

In short-cut hams, spoilage or incipient deterioration was usually observed to originate, or be localized, in fascia between the *adductor*, *sartorius*, and *vastus medialis* muscles at a point adjacent to the aitch bone. This area is one of very slow salt penetration and is a short distance (2 to 3 inches) from the exterior crosscut end of the ham. Short-cut hams may be vulnerable because of exposed channels that permit entrance of micro-organisms and air. Another very simple and logical factor might be that the long-cut ham has a greater surface area exposed to the curing mixture, pound for pound, than does the short-cut ham, and salt equalization is more rapid.

Comparisons of right and left pairs of short- and long-cut hams are shown in table 8. Results seem to indicate greater stability in the long-cut hams. In pair comparisons, long-cut style was best in 67 percent of the pairs. Long-cut hams had an average desirability of flavor of 2.8 and a range of 2.0 to 3.8, and short-cut hams averaged 2.4 and had a range of 0 to 3.8. Short-cut hams had a mean shrinkage of 17.2 percent and long-cut hams, 15.9 percent. The reason for the greater stability of the long-cut ham is not known.

Chemical and Organoleptic Analysis

Soluble nitrogen, nonprotein nitrogen, free fatty acids, peroxides, and sodium chloride were determined in addition to proximate composition. These characteristics changed, as described by Fields and Dunker (*8*) and Fields, Dunker, and Swift (*9*), and showed little

relation to the organoleptic quality of the hams. Desirability of flavor of the fat showed remarkably close correlation with desirability of flavor of the lean. Although hydrolytic and oxidative changes take place in the fatty tissue (*16*), these changes are not believed to cause bad flavors. The undesirable flavor appears to originate in the lean tissue and diffuses into the fat.

Bacteriological Studies

Results of bacteriological studies were similar to those reported by Fields, Dunker, and Swift (*9*). The relation of proper salt equalization, salt level, and salt-moisture ratio to keeping quality indicates that bacteria are a factor in the spoilage of aged hams. However, the role of micro-organisms in the aging of hams remains obscure. Total bacteriological count showed no relation to palatability, moisture content, or salt concentration. There was no correlation between stability and the large number of bacterial species isolated. Considerable sampling error might be involved because of variation in locality of activity. Furthermore, flora may change during storage and not be representative of the condition of the ham at time of testing.

SUMMARY AND CONCLUSIONS

The experiments reported here indicate that much of the spoilage in country-cured aged hams may be due to the wide variation in the ability of hams to absorb salt. Consequently, where minimum quantities are used, some hams will have salt levels that will not sufficiently counteract an abnormal predisposition to deteriorate. This is particularly true for dry-cured hams. Brine pumping plus brine curing seemed to give more uniform products. Brine curing was next. Regardless of the amount of curing mixture used, it is essential that the hams be held for a conditioning period at moderately low temperatures to allow salt equalization. Shrinkage (drying) accompanies salt distribution and is particularly important in brine-cured or brine-pumped plus brine-cured hams and hams with dangerously high salt-moisture ratios. Salt equalization and shrinkage occur naturally during the winter months on the farm if the modern advantages of the locker plant are not resorted to. Hams cured in the locker plant and brought home in warm weather may not be properly prepared for aging.

Smoking is advantageous since it tends to raise the general level of quality. However, it is not essential if the requirements of the other factors are satisfied.

The effect of the method of cutting ham remains obscure. Long-cut hams appeared to be more stable than short-cut hams. It is not certain to what degree the style of cutting might modify the importance of the factors studied, and this requires further investigation.

Chemical analyses were made of soluble nitrogen, nonprotein nitrogen, free fatty acids, peroxides, and sodium chloride; and bacteriological changes were studied. There was no apparent relation between the factors studied and the quality of the aged hams.

TABLE 7.—*Comparison of brine-cured and dry-cured hams*

Kind of cure [1]	Loss (−) or gain (+) during—						Salt-moisture ratio in muscles			Desirability of flavor of lean [2]
	Curing	Conditioning before smoking		Smoking 3 days at 130° F.	Conditioning 4 months outside in winter	Storage 4 months	*Semimembranosus*	*Vastus intermedius*	*Biceps femoris*	
Brine:	*Percent*	*Days*	*Percent*	*Percent*	*Percent*	*Percent*				*Score*
14 percent	+3. 46	18	+0. 54	−5. 22	----------	----------	1:10. 4	1:13. 5	1:21. 2	3. 8
12.5 percent	+3. 84	18	+. 33	−5. 96	----------	----------	1: 9. 7	1:11. 0	1:18. 5	3. 8
10.2 percent	+1. 41	18	−2. 89	−9. 13	----------	----------	1:12. 5	1:20. 3	1:22. 1	3. 8
Dry cure	−5. 03	43	−9. 80	−12. 89	----------	----------	1: 9. 8	1: 9. 0	1:13. 3	3. 8
Brine:										
14 percent	0	7	−1. 22	--------	−23. 46	[3] −30. 62	1: 4. 9	1: 5. 0	1: 4. 8	2. 7
12.5 percent	+3. 64	10	−2. 12	--------	−16. 22	[3] −23. 03	1: 7. 5	1: 6. 6	1: 7. 4	3. 5
10.2 percent	+6. 36	7	−4. 30	--------	−18. 29	[3] −27. 29	1: 7. 1	1: 6. 9	1: 6. 7	1. 7
Dry cure	−4. 67	43	−9. 41	--------	−22. 71	[3] −29. 29	1: 6. 8	1: 6. 7	1: 5. 9	2. 8
Brine:										
14 percent	+3. 25	10	+1. 95	−4. 08	−19. 50	[3] −26. 71	1: 4. 2	1: 4. 9	1: 5. 0	4. 0
12.5 percent	+5. 27	18	+1. 59	−3. 96	−19. 04	[3] −26. 75	1: 9. 7	1: 6. 4	1: 6. 5	3. 1
10.2 percent	+5. 21	10	+3. 63	−3. 02	−19. 40	[3] −27. 80	1: 6. 2	1: 6. 5	1: 6. 5	2. 8
Dry cure	−4. 11	43	−9. 30	−12. 07	−22. 90	[3] −30. 48	--------	--------	--------	2. 5
Brine:										
14 percent	+5. 70	10	+3. 66	--------	−14. 71	[3] −21. 84	1: 5. 2	1: 5. 2	1: 5. 0	3. 3
12.5 percent	−. 17	7	−1. 29	--------	−22. 73	[3] −30. 75	1: 4. 6	1: 6. 2	1: 6. 6	1. 8
10.2 percent	+5. 28	17	−1. 37	--------	−18. 97	[3] −27. 70	1: 7. 2	1: 5. 4	1: 6. 1	1. 7
Dry cure	−2. 17	43	−7. 77	--------	−19. 26	[3] −26. 17	1: 8. 3	1: 7. 2	1: 7. 3	3. 2
Brine:										
14 percent	+1. 77	17	−4. 74	−10. 55	----------	[4] −28. 90	1: 5. 4	1: 5. 1	1: 5. 7	2. 3
12.5 percent	+1. 55	18	−2. 06	−8. 43	----------	[4] −25. 23	1: 7. 5	1:10. 0	1: 7. 5	1. 8
10.2 percent	+3. 97	25	−2. 36	−7. 41	----------	[4] −25. 80	1: 7. 9	1: 5. 2	1: 3. 5	2. 3
Dry cure	−3. 68	43	−8. 39	−12. 08	----------	[4] −24. 10	1: 4. 9	1: 6. 6	1: 6. 8	3. 5

Brine:										
14 percent	0	14	−2. 11	−7. 96	−23. 60	[4] −32. 10	--------	1: 4. 2	1: 4. 3	2. 7
12.5 percent	+5. 55	10	+3. 97	−2. 98	−18. 60	[4] −26. 60	1: 5. 1	1: 6. 5	1: 6. 3	3. 3
10.2 percent	+6. 88	17	+3. 54	−2. 10	−16. 96	[4] −24. 36	1: 5. 6	1: 6. 1	1: 7. 2	3. 0
Dry cure	−4. 23	43	−9. 09	−12. 63	−23. 52	[4] −30. 98	--------	--------	--------	1. 8

[1] Curing was as follows: 14-percent salt brine, 10–8–2 formula made to 91° s.g.; 12.5-percent salt brine, 9–8–2 formula made to 81° s.g.; 10.2-percent salt brine, 8–8–2 formula made to 71° s.g. All brine-cured hams were cured 4 days per pound. Dry curing was with 8–8–2 formula per 100 pounds for 2 days per pound.

[2] 14-percent salt brine: Average, 3.1; range, 2.7–3.8. 12.5-percent salt brine: Average, 2.7; range, 1.8–3.5. 10.2-percent salt brine: Average, 2.3; range, 1.7–3.0. Dry cure: Average, 2.8; range, 1.8–3.5.

[3] Outside in summer.

[4] At 70° F.

TABLE 8.—*Comparison of long- and short-cut hams cured by different methods*

Cure, and paired cut	Loss (−) or gain (+) during—			Salt	Desirability of flavor of lean
	Curing	Smoking (2 days at 120° F.)	Storage (4 months at 700° F.)		
Brine-pumped plus brine-cured:	*Percent*	*Percent*	*Percent*	*Percent*	*Score*
Long-cut (right)	+10. 5	--------	−17. 9	6. 26	2. 2
Short-cut (left)	+12. 3	--------	−19. 8	7. 06	1. 6
Long-cut (right)	+8. 9	--------	−24. 2	7. 42	2. 8
Short-cut (left)	+9. 5	--------	−20. 2	7. 02	2. 0
Long-cut (right)	+12. 8	--------	−14. 5	6. 99	3. 8
Short-cut (left)	+12. 2	--------	−13. 1	6. 77	3. 6
Long-cut (right)	+10. 6	--------	−18. 2	6. 57	2. 4
Short-cut (left)	+10. 7	--------	−19. 6	6. 97	3. 0
Long-cut (right)	+11. 7	+4. 8	−10. 8	6. 31	3. 8
Short-cut (left)	+10. 0	+2. 6	−13. 2	6. 14	3. 8
Long-cut (right)	+8. 7	−. 4	−17. 4	6. 02	2. 8
Short-cut (left)	+8. 5	0	−16. 3	9. 61	3. 4
Long-cut (right)	+7. 1	−. 71	−19. 5	9. 4	3. 0
Short-cut (left)	+9. 6	--------	−20. 3	8. 18	2. 8
Brine-cured:					
Long-cut (right)	+1. 0	--------	−16. 8	8. 6	2. 6
Short-cut (left)	+. 83	−5. 70	−22. 3	8. 0	2. 2
Brine-pumped plus dry-cured:					
Long-cut (right)	+3. 2	−2. 3	−17. 6	5. 53	2. 0
Short-cut (left)	+3. 0	−3. 0	−17. 4	6. 11	2. 8
Long-cut (right)	+5. 49	−. 23	−9. 4	--------	2. 4
Short-cut (left)	+5. 3	−. 29	−9. 7	--------	2. 2
Long-cut (right)	+3. 3	−1. 9	−14. 4	8. 3	2. 4
Short-cut (left)	+1. 0	−7. 2	−21. 9	8. 1	0
Long-cut (right)	+5. 8	+. 30	−10. 4	10. 1	3. 6
Short-cut (left)	+3. 5	−1. 74	−12. 2	8. 6	2. 3

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